Third United Nations International Conference on the Peaceful Uses of Atomic Energy

A/CONF.28/A/261
UNITED STATES
February 1964
Original: ENGLISH

Confidential until official release during Conference

Abstract

DEVELOPMENTS IN TRANSPORT THEORY

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Recent efforts to broaden the theoretical base of neutron and photon transport include (1) systematic derivation of a transport equation from the formalism of quantum field theory using coarse-grained density distributions; (2) use of probability-generating functions together with first-collision equations to formulate a stochastic theory of neutron transport, including arbitrary deviations from the mean; and (3) invariant imbedding methods wherein the usual Boltzmann or transport equations with conditions at two boundaries are replaced by non-linear equations with conditions at a single boundary.

Recent achievements in the classical analysis of the transport equation and related linear integral equations are considered. The properties of the spectrum of eigenvalues of the transport operator are reviewed, and the method of expanding general solutions in terms of a complete set of eigenfuctions is outlined. Extensions of the eigenfunction expansion method from plane to curved geometries, from isotropic to more general scattering laws, and from monoenergetic to energy-dependent problems are sketched. Limitations and potential extensions of the method are noted.

Recent developments in integral theory and variational methods are summarized, including methods yielding a result with an error of high order in the trial function error. The analytic section of the paper concludes with a review of some

of the useful transformations and simplifications of the transport equation, in particular of its source term.

The second section of the paper is concerned with numerical methods. The generalized discrete-ordinates multi-group method is first discussed beginning with formulation of integral equations, called mesh cell balance equations. Various simplifications, in particular diffusion theory, are considered in this framework.

Next, the application of difference schemes to the balance equation is discussed, and then the rules for evaluating the resulting recursion formulas are described. Here the major concern are the control of errors, the handling of implicit source terms and boundary conditions, and the convergence of multi-level iterative processes. The matter of inner, outer, and eigenvalue iterations and associated convergence test is examined briefly.

Methods that minimize or dispense with inner iterations are noted in connection with the diffusion equation. Here the reflection method, related to the concept of invariant imbedding, is extended to multi-dimensional problems. Advances in the techniques for solving the second-order form of the diffusion equation and the extension of these techniques to the transport case are noted. Some numerical comparisons of various solution methods are presented.

Finally, progress in non-discrete numerical techniques, in Monte Carlo procedures, and in combination of the latter with deterministic methods is summarized.